Case Studies of *Intelligent Compaction*

Ervin Dukatz, PH.D, P.E.

Mathy Construction Co.

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Intelligent Compactors

- Why intelligent compactors (IC)?
- Are they “plug and play”?
- What accessories are needed?
- Where can they be used on a project?
- Data: What, Where, When and How?
- Where have they been used?
- And...?

Why intelligent compactors (IC)?

The Problem:

Are the pavement layers well compacted:

- Subgrade,
- Base, and
- HMA?

How do you measure?

Current Methods

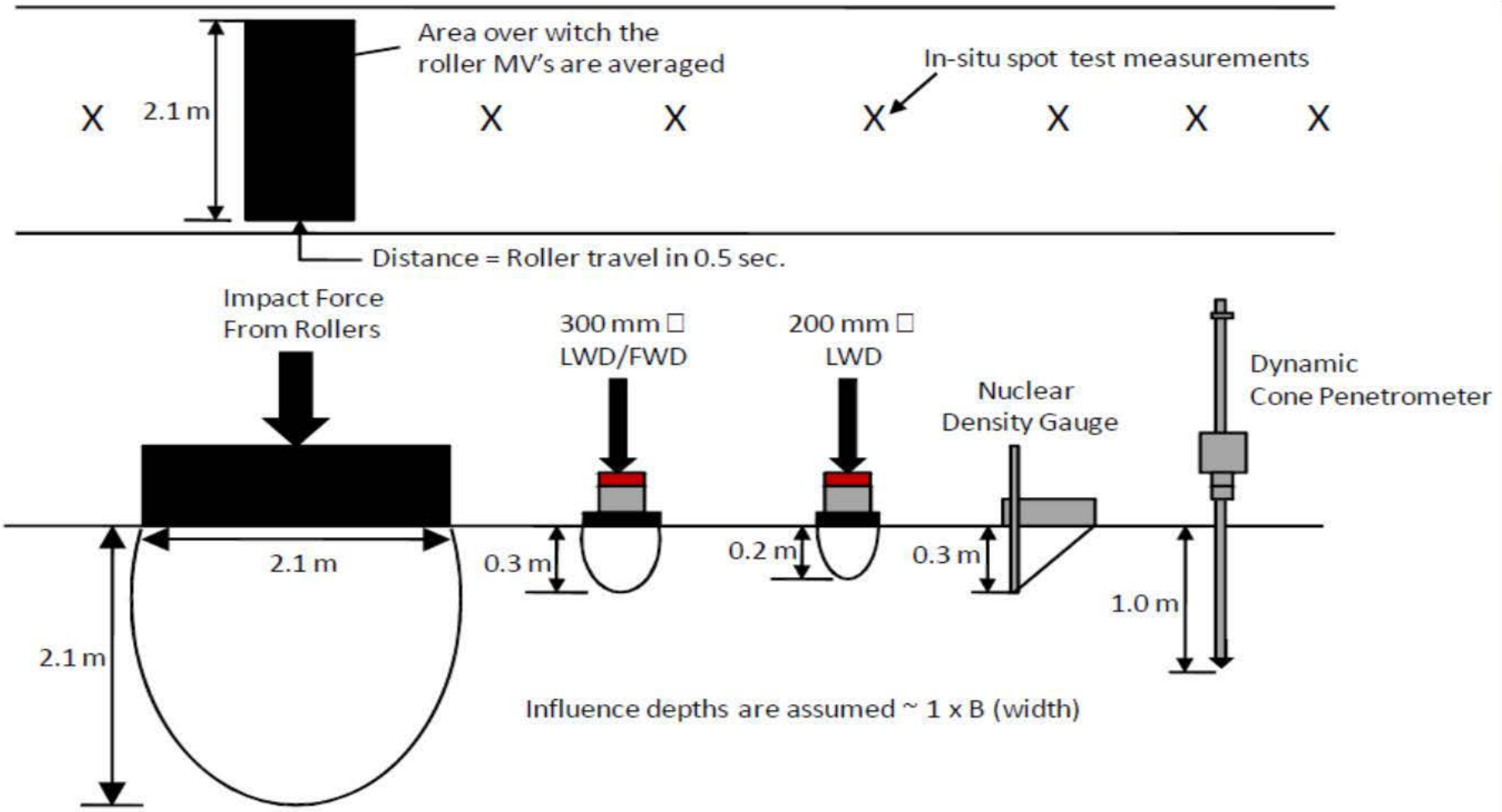
- Post Construction
- Measured at Random Locations


NG measuring

What is Needed?

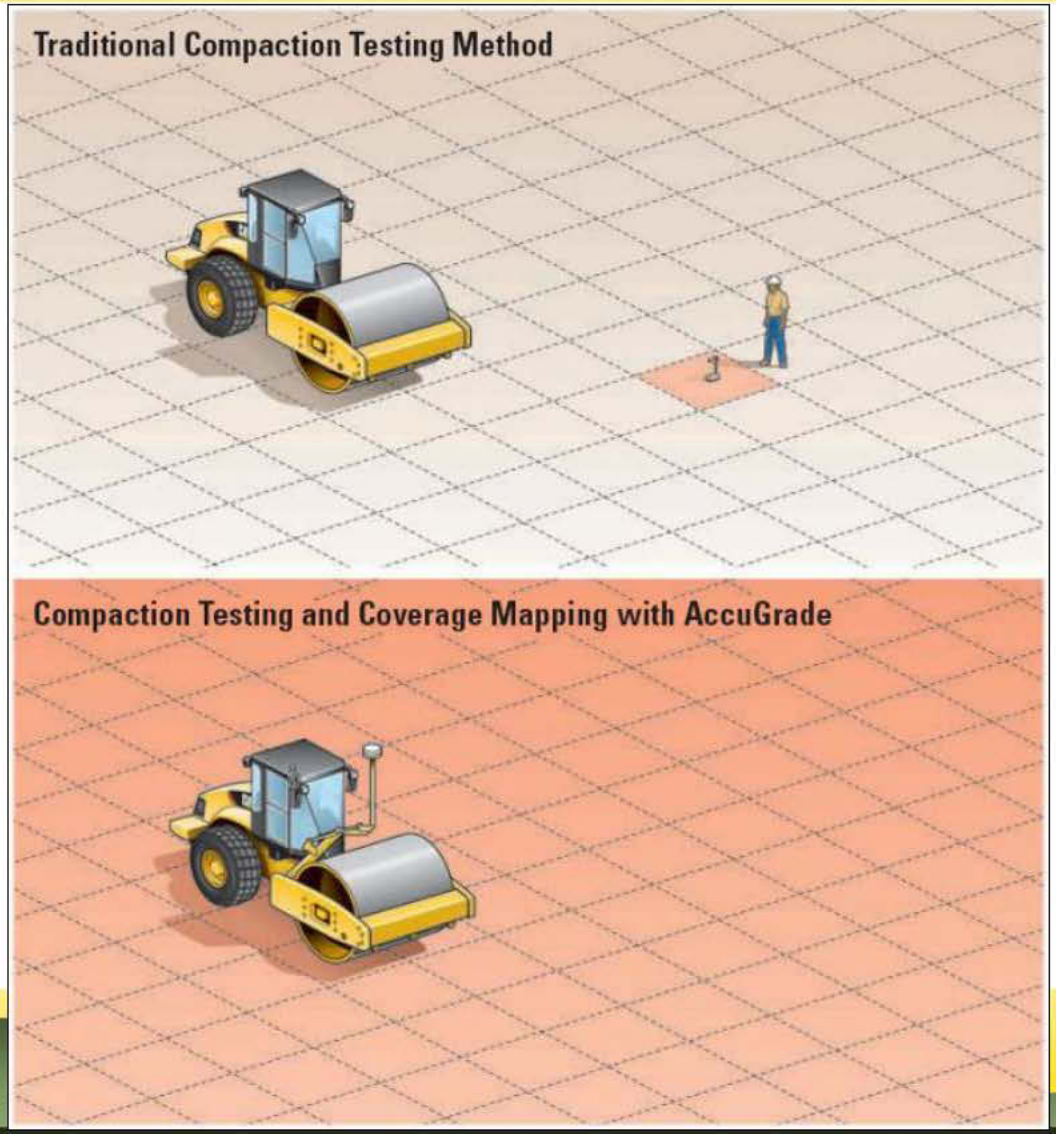
- Real-time
  - Control
  - Measurements

Why Intelligent Compactors?



(Courtesy of Dr. David White)

Sampling Coverage



1 / 1,000,000

100 % Coverage

Courtesy of Trimble/Caterpillar

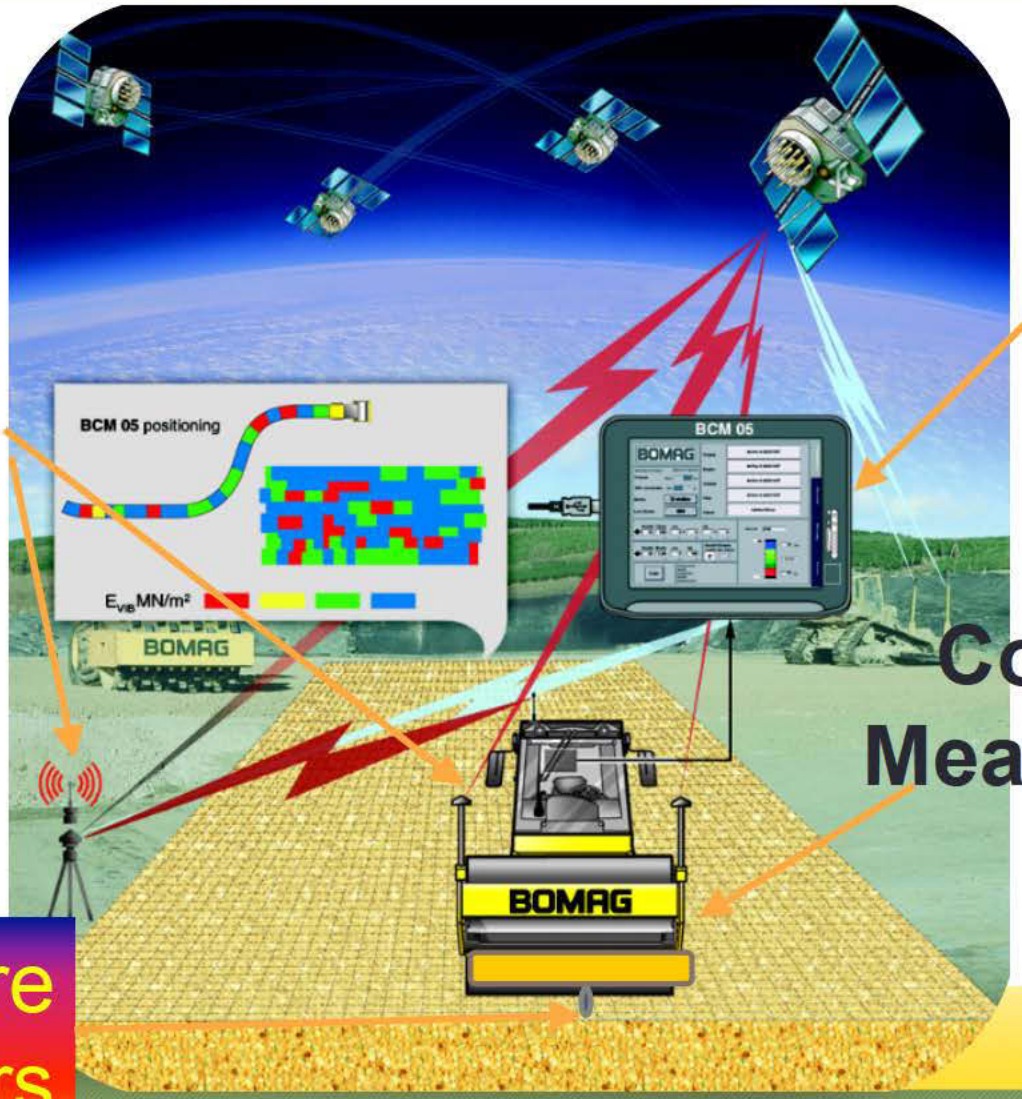
Are they “plug and play”?

Some assembly needed:

- Accessories
- Calibrations
- Training
  - Operators
  - Managers
  - Owner/Agency

What accessories are needed?

Global Positioning System GPS



Onboard Report System

Continuous Measurement System

Temperature Sensors

Courtesy of Bomag

Where to use IC rollers?

- Preconstruction site survey
- Mapping the project
- QC during construction
- Acceptance / Proof Rolling

Data: What, Where, When and How?

Real time display shows the mapped:

- Roller pass locations
- Number of passes
- ***Stiffness value (RM***
- Option:
  - Temperature(s)

RMV(Roller Measurement Values)

Ammann

k_b

Caterpillar

CMV, MDP

HAMM/Wirtgen

HMV

Bomag

E_{VIB}

Dynapac

CMV

Sakai

CCV

Courtesy Transtec, Inc.

Notes on RMV

- RMV only measured with rollers with a vibrating drum.
- RMV only measured with vibrators turned on.
- Currently, RMV is unique to:
  - Manufacturer
  - Roller model
- RMV = E*, G* or M_R
- RMV standard(s) needed.

IC, Where are you?

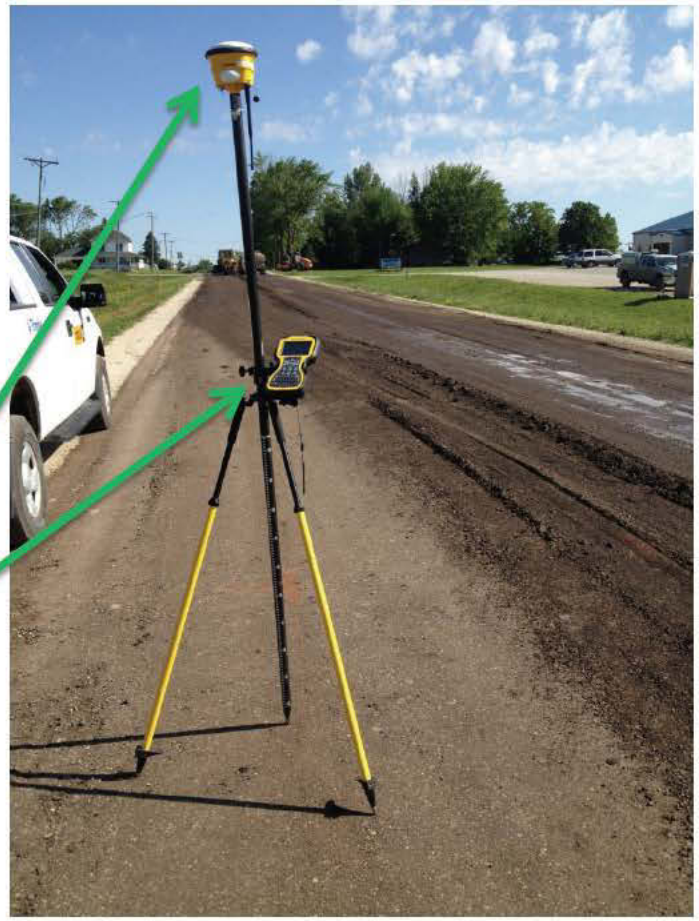
- Local positioning
- VRS – virtual reference system
  - Need 100% cellular coverage
  - Problems?
- RTK(real-time kinetic)-GPS
  - Need master/local base station
  - Repeaters and Rover
  - 100% coverage
  - Problems?

Location of Base Station

- Undisturbed by everyday activities.
- GPS needs coordinate system set
- Line of sight needed between IC(s), base station and repeaters
- Additionally: spare *Batteries*

(GPS) Rover

- GPS Instrument used to:
  - ü set up base station
  - ü Tie into local or state coordinate system
  - ü Mark test locations
  - ü Check calibrations.



- GPS Receiver
- Controller

How is the Data collected?

A short history.

- 2004 MnDOT first uses IC at MnRoad
- 2006 Mathy first trial with IC
- 2010 Mathy TPF 954 with WisDOT on I39
- 2010 Mathy SFDR Mn-16
- 2012 Mathy with MnDOT
  - Th 56 and 57
  - CSAH 16

BOMAG 190AD IC Roller-E$_{VIB}$

- Found utilities and soft spots random testing by density gauge missed.
- Monitor display

BOMAG 190AD IC Roller

2007 I94 Wisconsin

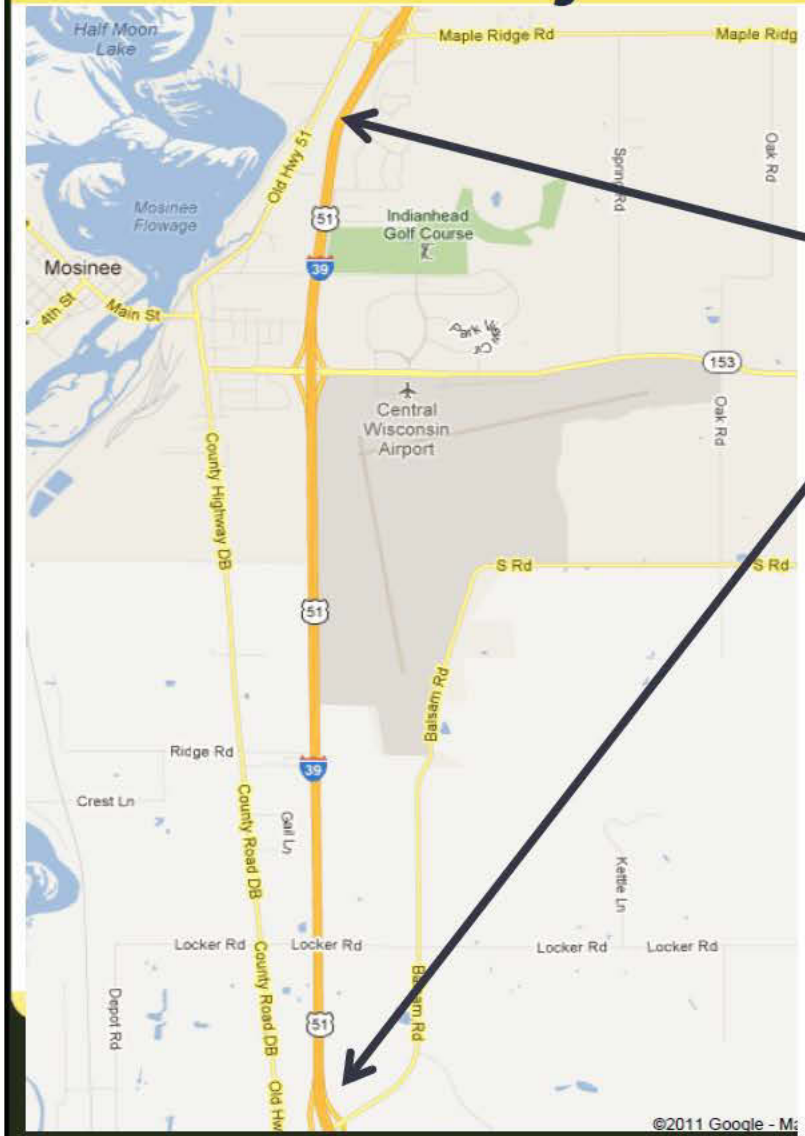
- PCC slabs rocking
- E_{VIB} prevented
- Operator

Sakai SW 880 IC Roller-CCV

2008 I35 Iowa

- used in TPF954
- CCV ≠ E_{VIB}

2010 Project Overview- I39



- WisDOT Proj. No. 1166-00-76
- Net Centerline Length: 5.7 mi
  - Start: Maple Ridge Road
  - Finish: Sth 34 (Balsam Rd)
- Project description:
  - Mill and remove existing HMA
  - Rubbilize or crack-and-seat PCC
  - Overlay with HMA
- IC used for mapping and compaction
- Manual Data Collection

Unique Features

- First TPF 954 IC demo to pave HMA on rubbilized and crack-and seat PCC base.
- First IC Demo to use IC rollers from “the ground up:
  - Mapping the rubbilized PCC base
  - Mapping the crack-and-seat PCC base
  - Compaction of HMA base, intermediate and surface layers.

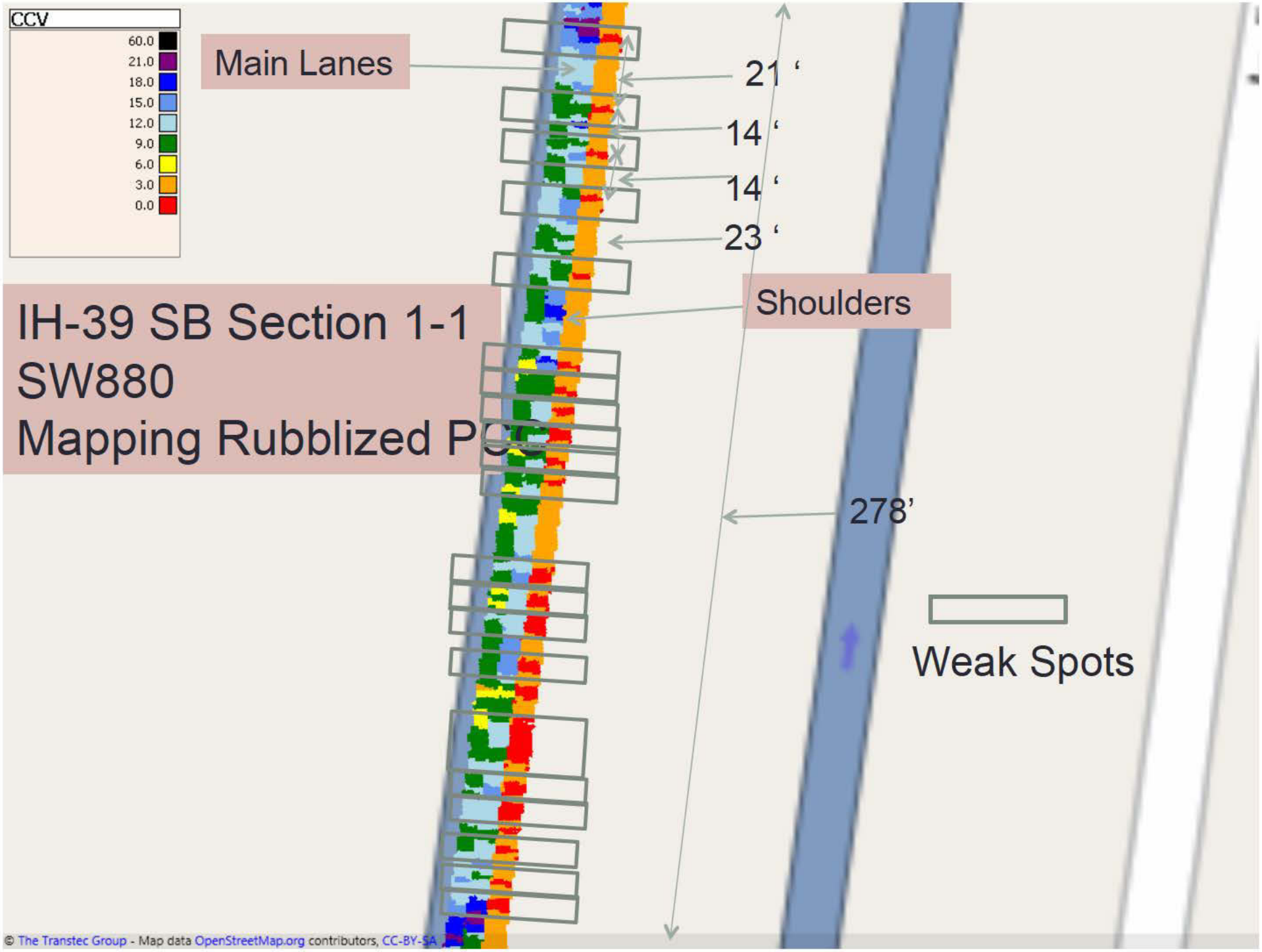
Equipment

SW 880 Tandem IC Roller

Trimble Navigation Limited base station

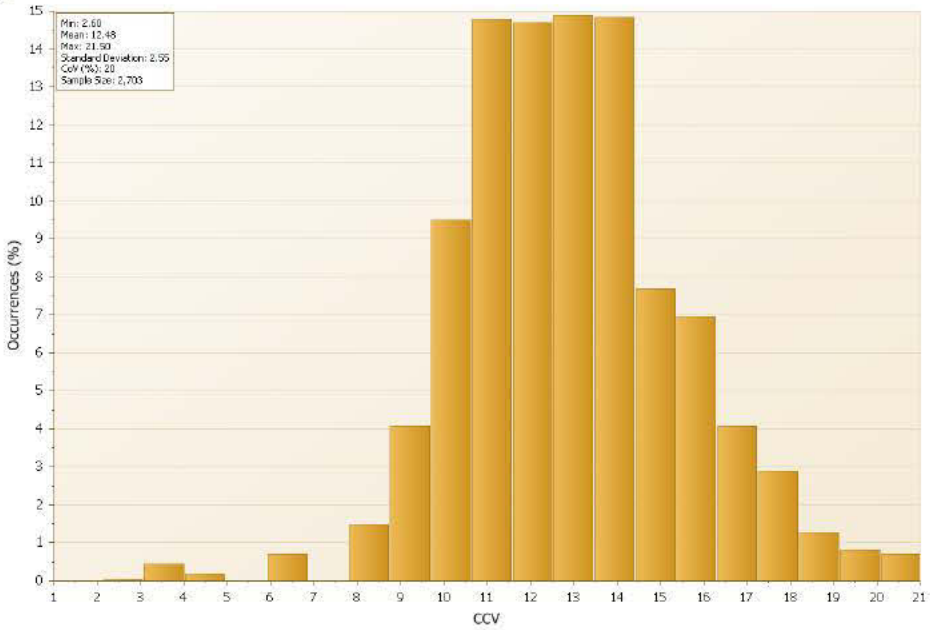
SW 990 Tandem IC Roller

Topcon Positioning Systems Base station

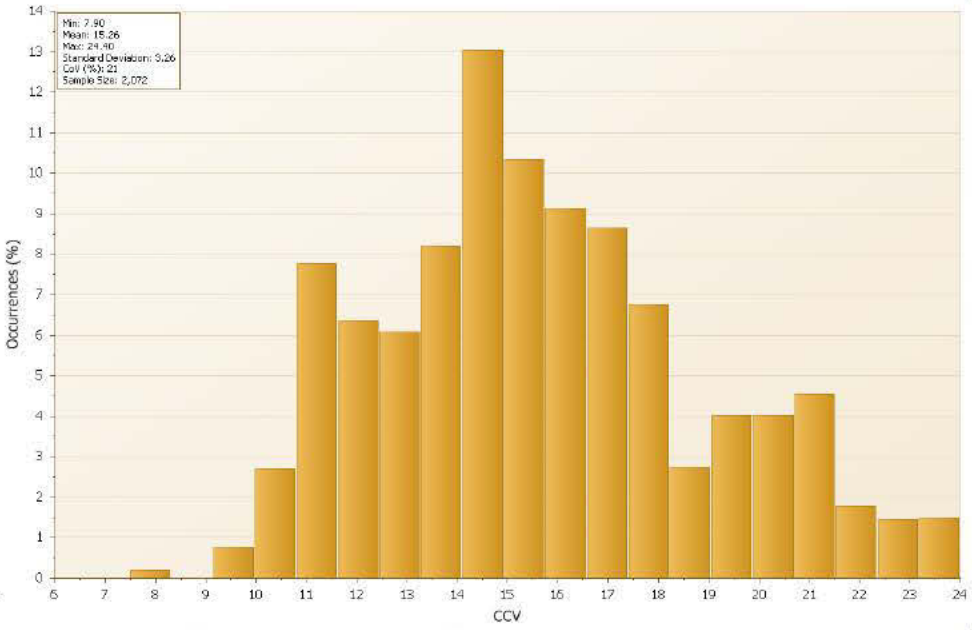

CCV
60.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
Main Lanes
21 ‘
14 ‘
14 ‘
23 ‘
Shoulders
IH-39 SB Section 1-1
SW880
Mapping Rubblized P
278’
Weak Spots
© The Transtec Group - Map data OpenStreetMap.org contributors, CC-BY-SA

Mapping Main Lanes Section 1-1

Rubblized PCC



HMA Surface Course



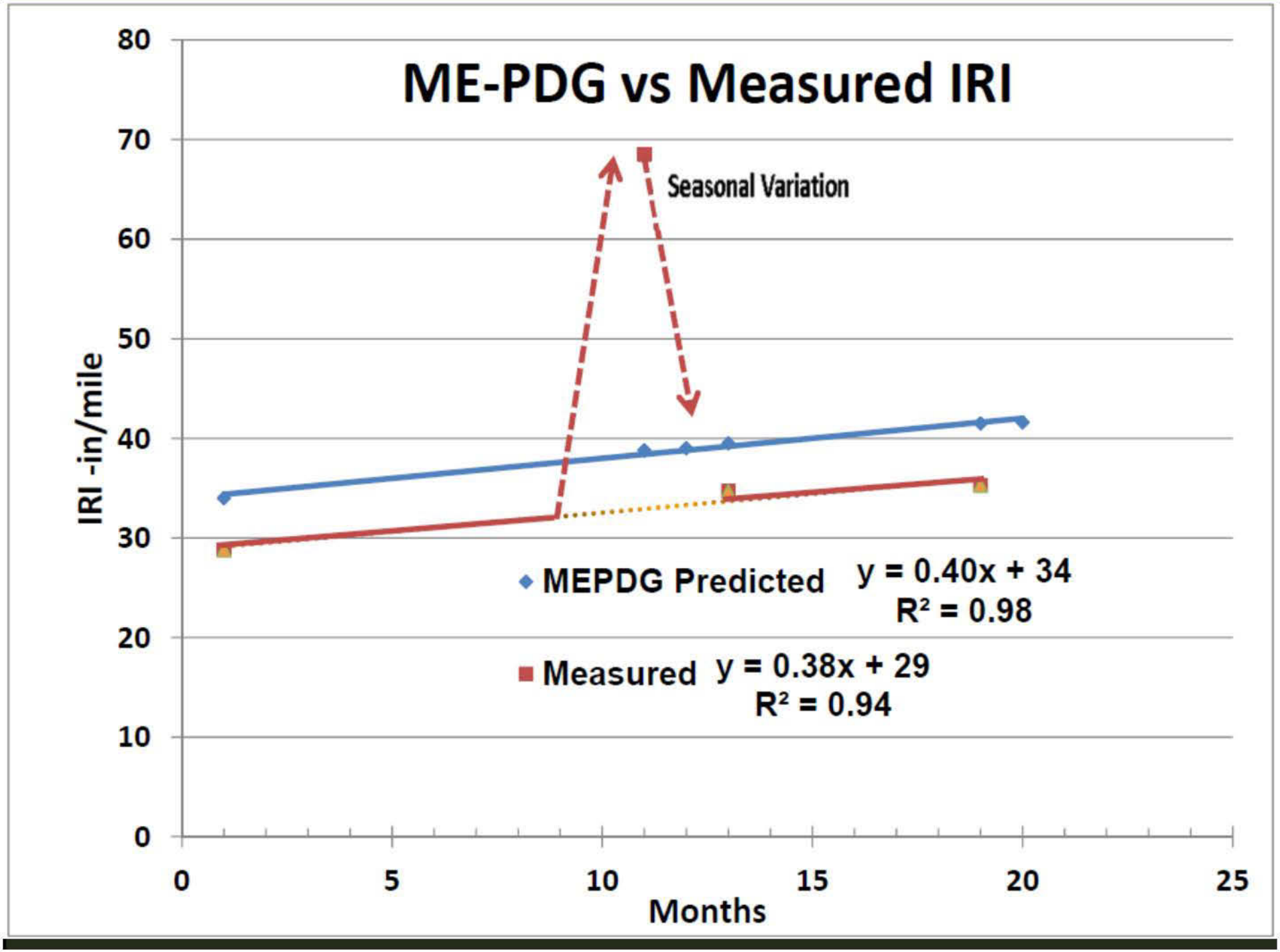
Mean CCV = 12.5

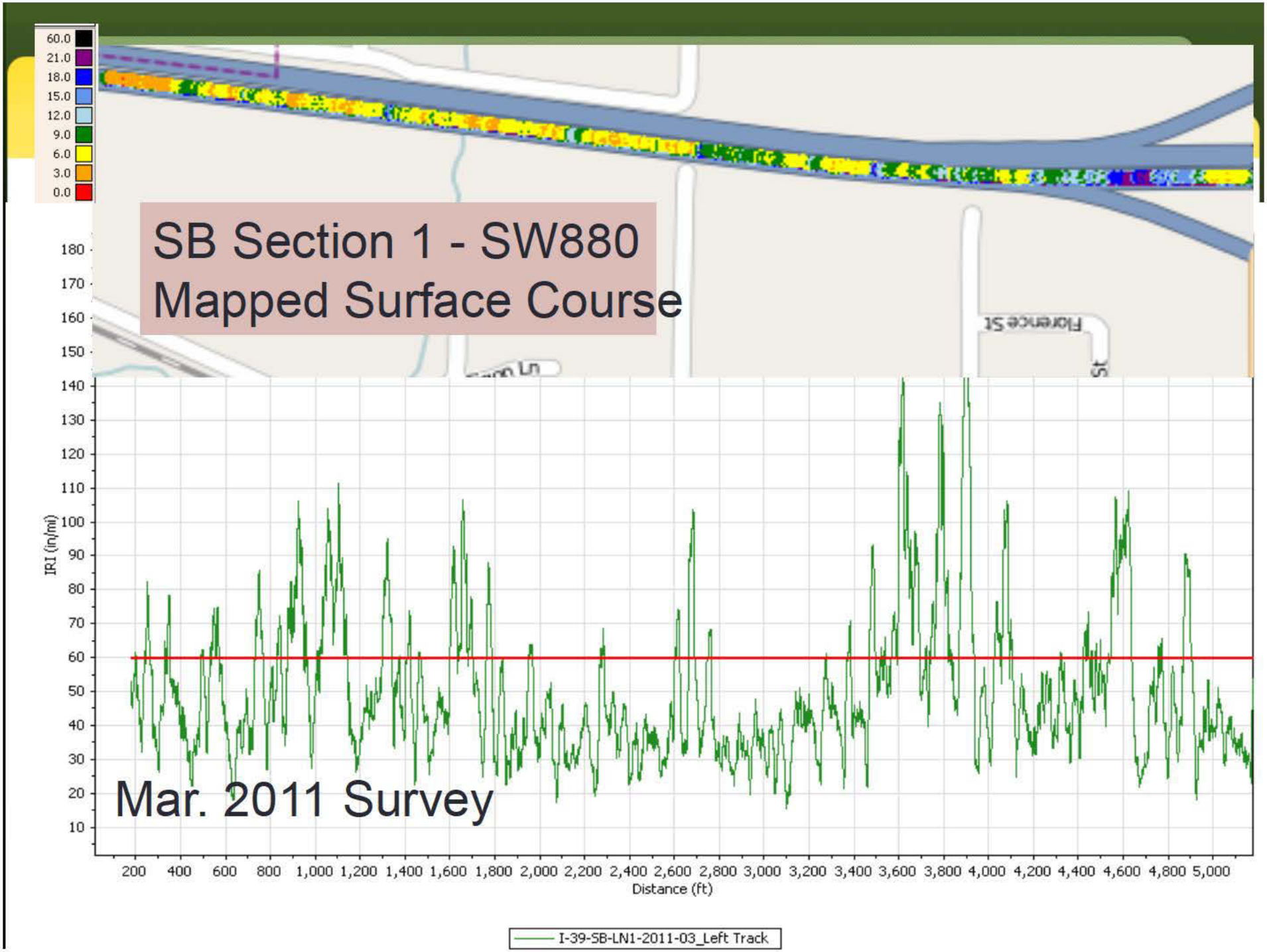
Mean: CCV = 15.3

%Gmm = 93.5

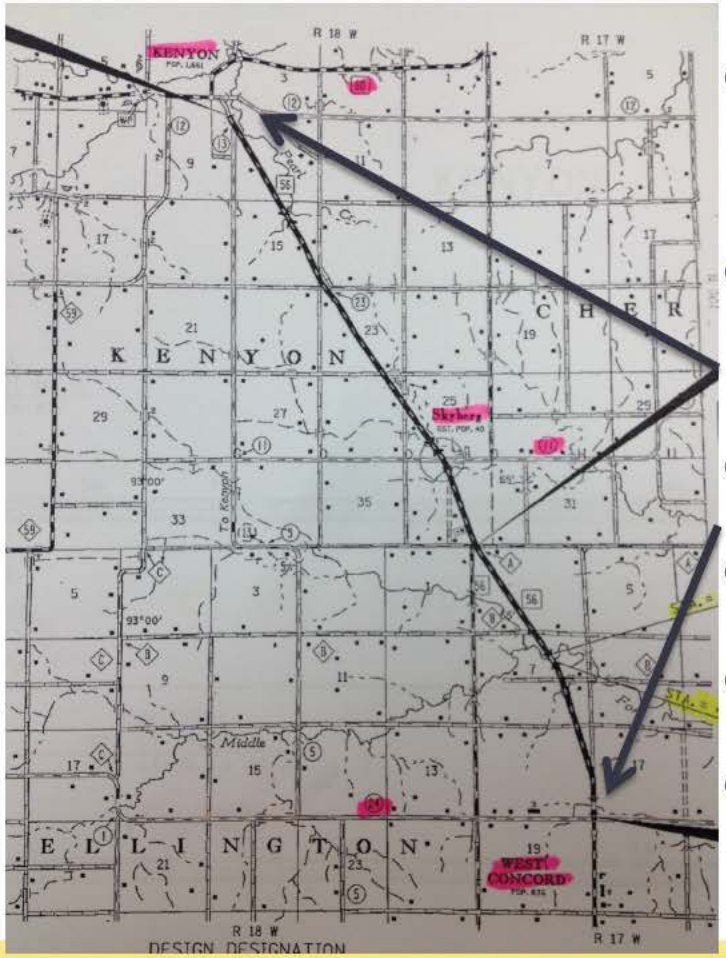
IRI = 29.8in/mile

Compaction Control Value Increases from ground up


ME-PDG vs Measured IRI
Seasonal Variation
IRI -in/mile
Months
MEPDG Predicted
y = 0.40x + 34
R² = 0.98
Measured
y = 0.38x + 29
R² = 0.94
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25

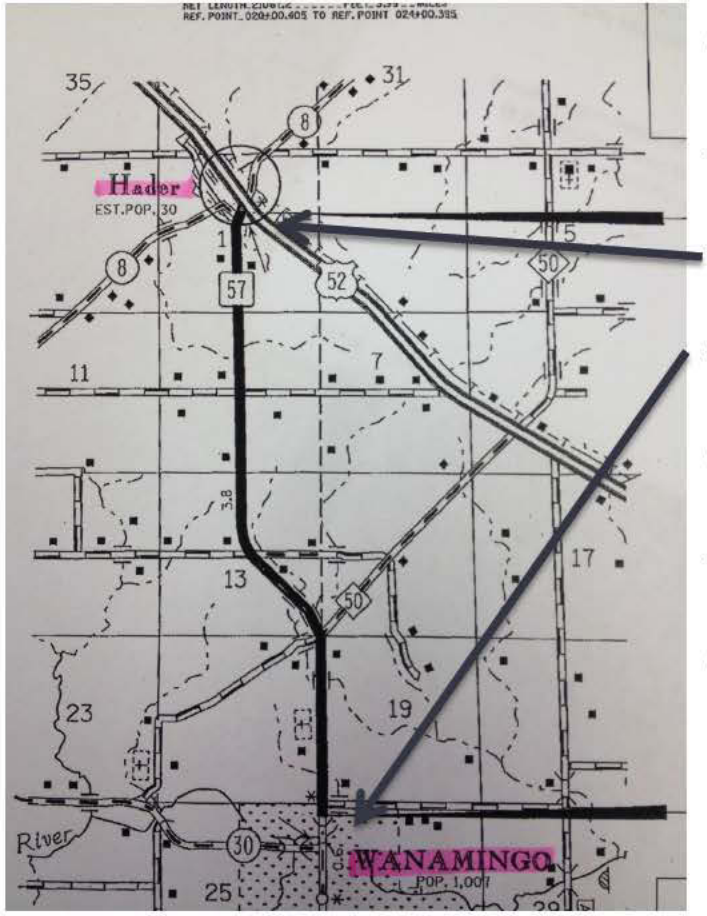

60.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
SB Section 1 - SW880
Mapped Surface Course
Florence St
IRI (in/mi)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Mar. 2011 Survey
200 400 600 800 1,000 1,200 1,400 1,600 1,800 2,000 2,200 2,400 2,600 2,800 3,000 3,200 3,400 3,600 3,800 4,000 4,200 4,400 4,600 4,800 5,000
Distance (ft)
I-39-SB-LN1-2011-03_Left Track

2012 Project Overview-TH 56



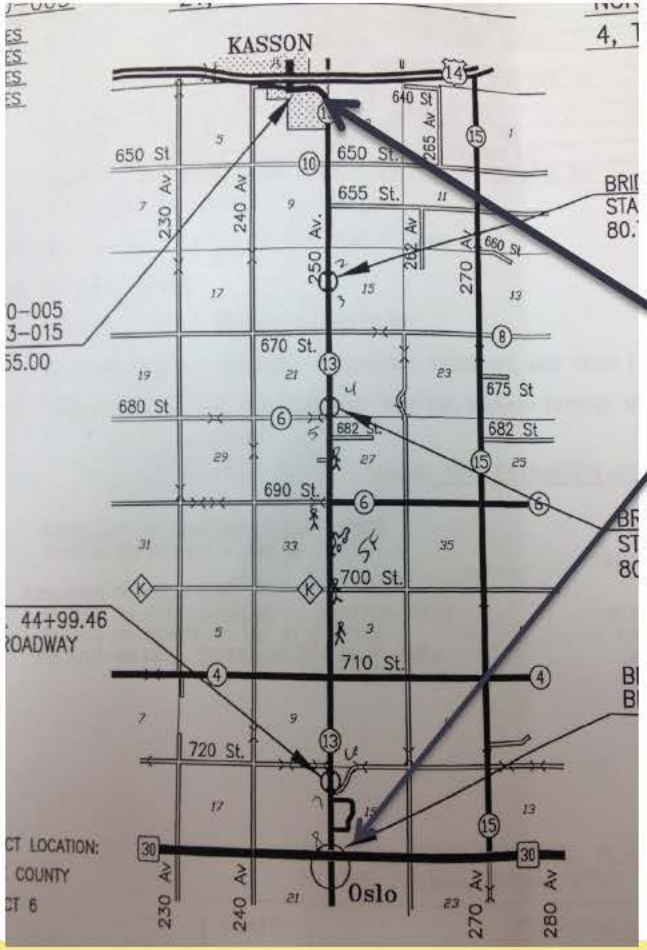
- MnDOT Proj. No. 2507-21 & 2006-27
- Net Centerline Length: 9.14 Miles
- Start: Kenyon, MN
- Finish: West Concord, MN
- Mill surface, SFDR, HMA
- IC equipment used through all phases.

2012 Project Overview-TH 57



- MnDOT Proj. No. 2509-22
- Net Centerline Length: 3.99 Miles
- Start: Hader, MN
- Finish: Wanamingo, MN
- Bituminous Mill & Overlay
- IC equipment used through paving.

2012 Project Overview-CSAH 13



- Proj. No. 020-613-015 & 020-070-005
- Net Centerline Length: 9.324 Miles
- Start: Kasson, MN
- Finish: TH 30
- FDR, HMA Surfacing, Aggregate Shouldering
- IC equipment used through all phases.

Roller Equipment

- Used or New roller?
  - Lead time
- What IC equipment is on the roller?
  - GPS Receiver
  - Sensors (stiffness vibratory rollers only)
  - Radio
  - Monitor

Trimble IC Retrofit System Used

(CCS900 Components)

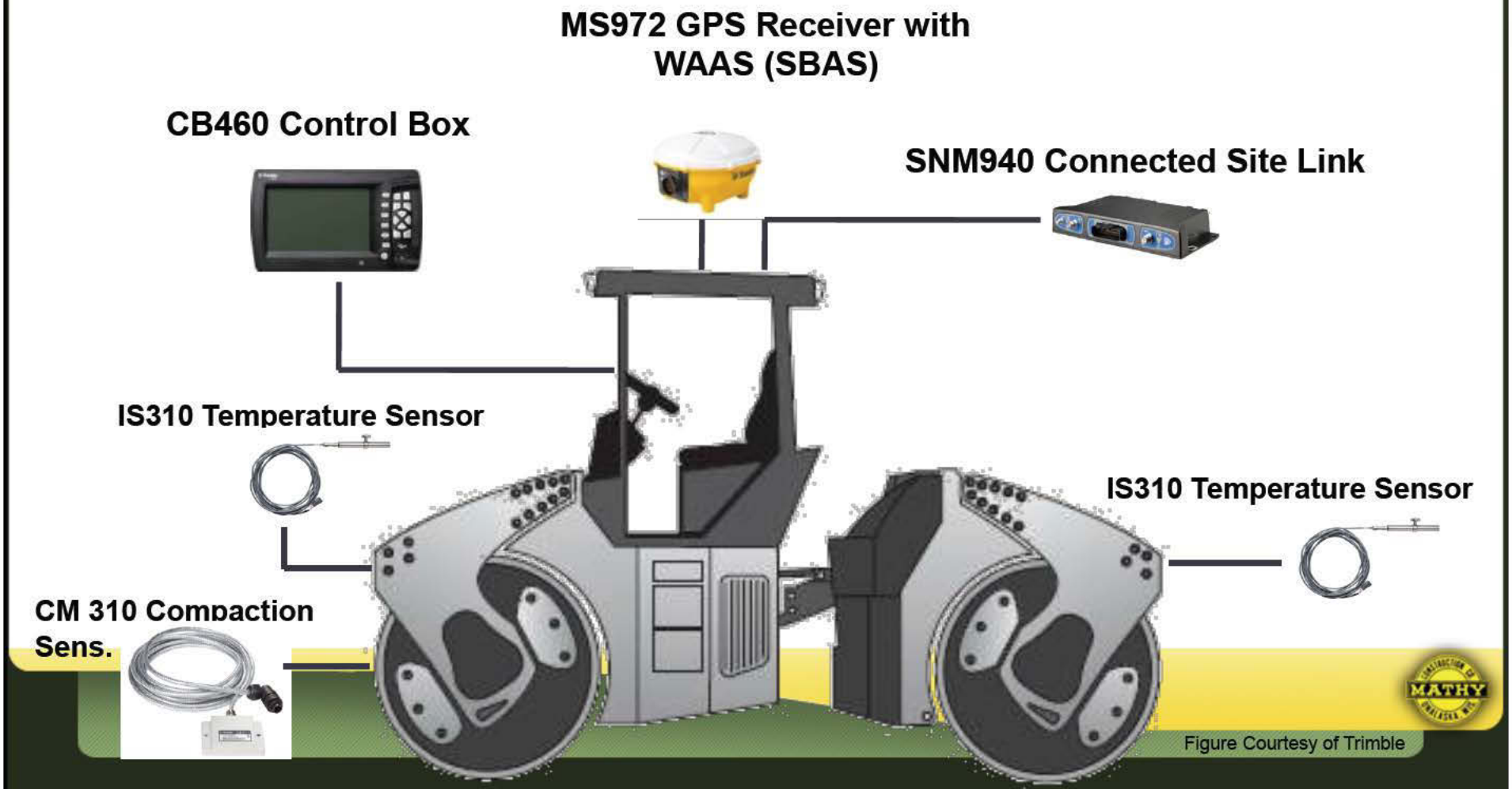


Figure Courtesy of Trimble

Instrumented Entire Rolling Train

Stabilized / Un-stabilized Full Depth Reclamation (FDR)

HMA Paving Train

Courtesy of Rebecca Embacher, MnDOT

Testing Matrix

Pre-Grind
- IC
- Nuke
- DCP
- LWD
- FWD

Stabilization
- IC
- Nuke
- LWD
- FWD

Before Paving
- FWD
- Digital Test Rolling

HMA Base Course
- IC
- Nuke
- LWD
- FWD
- PAVE-IR

HMA Wearing Course
- IC
- Nuke
- LWD
- FWD
- PAVE-IR
- GPR

Courtesy of Rebecca Embacher, MnDOT

Daily Setup

- IC manager

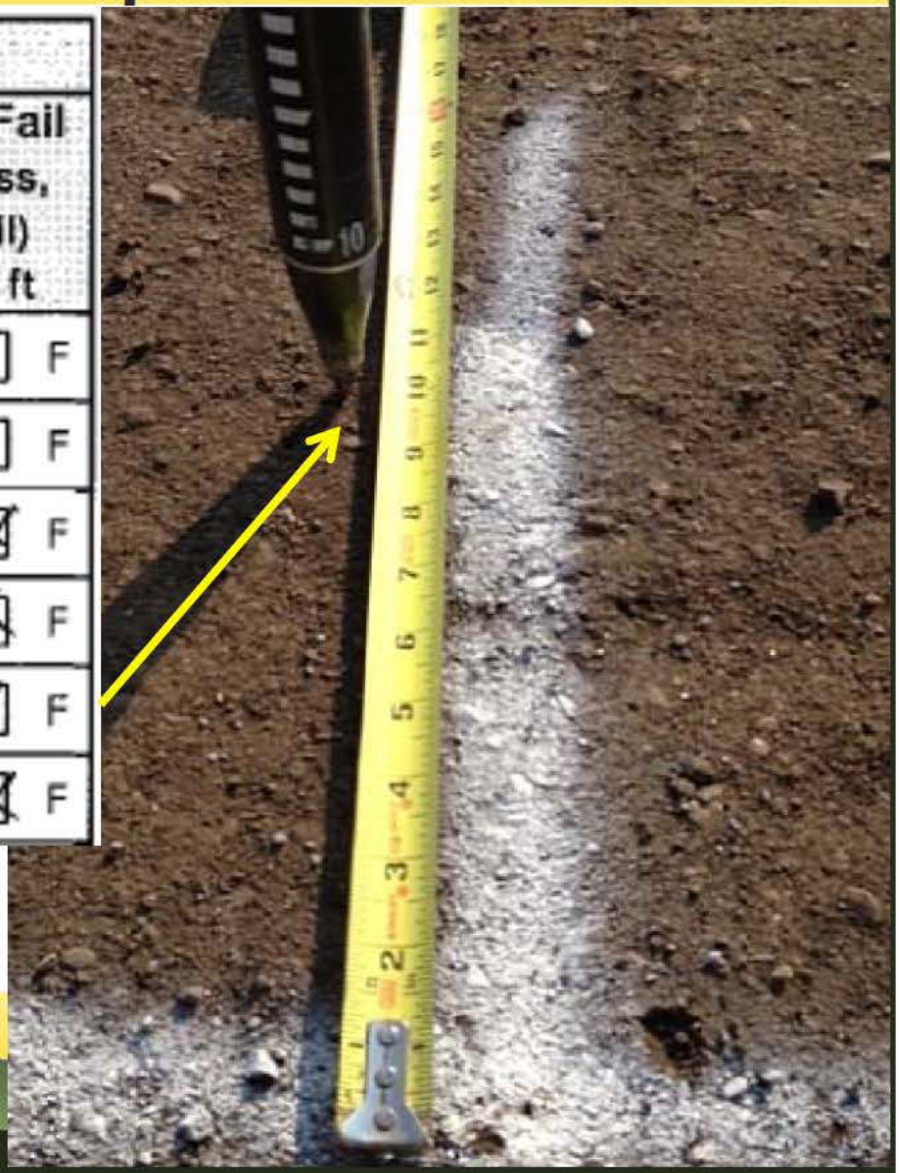
  (Calibrate Rollers)

  – ±6in. Tolerance Between roller and Rover

  – Time

Calibration – oops!

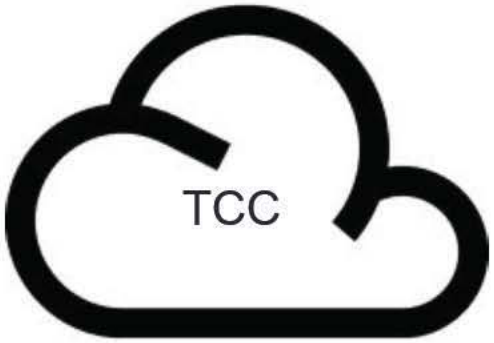
Accuracy		
Δ Northing	Δ Easting	Pass / Fail (P = Pass, F = Fail) P ≤ 0.5 ft
abs [(A) - (C)]	abs [(B) - (D)]	
0.10	0.21	☒ P ☐ F
0.03	0.21	☒ P ☐ F
0.70	0.57	☐ P ☒ F
0.53	0.60	☐ P ☒ F
0.96	0.75	☐ P ☒ F
0.26	1.20	☐ P ☒ F



- Plan for the unexpected.

Communication

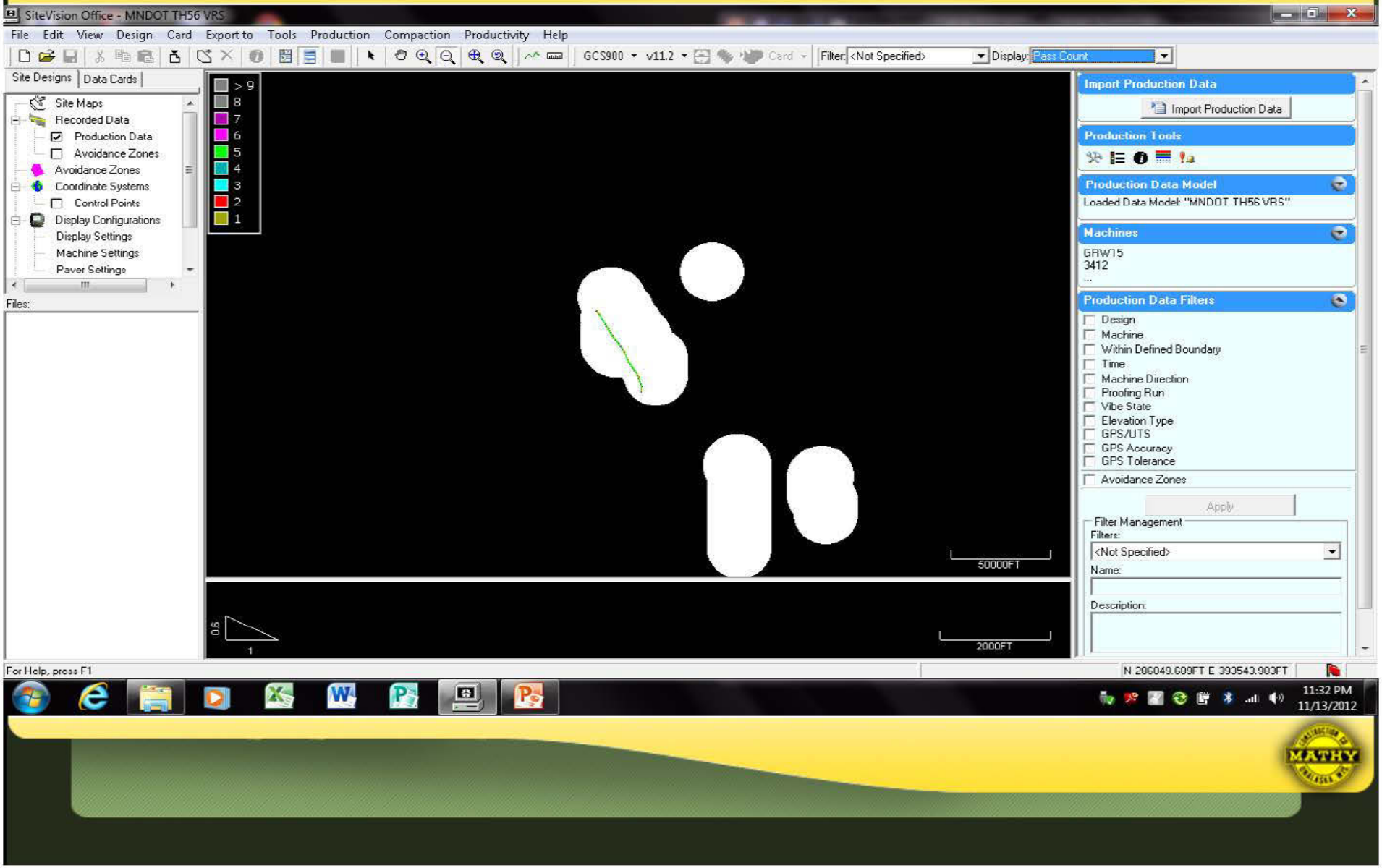
- Manual Data Collection – 40% loss
- Automatic Data Collection <1%



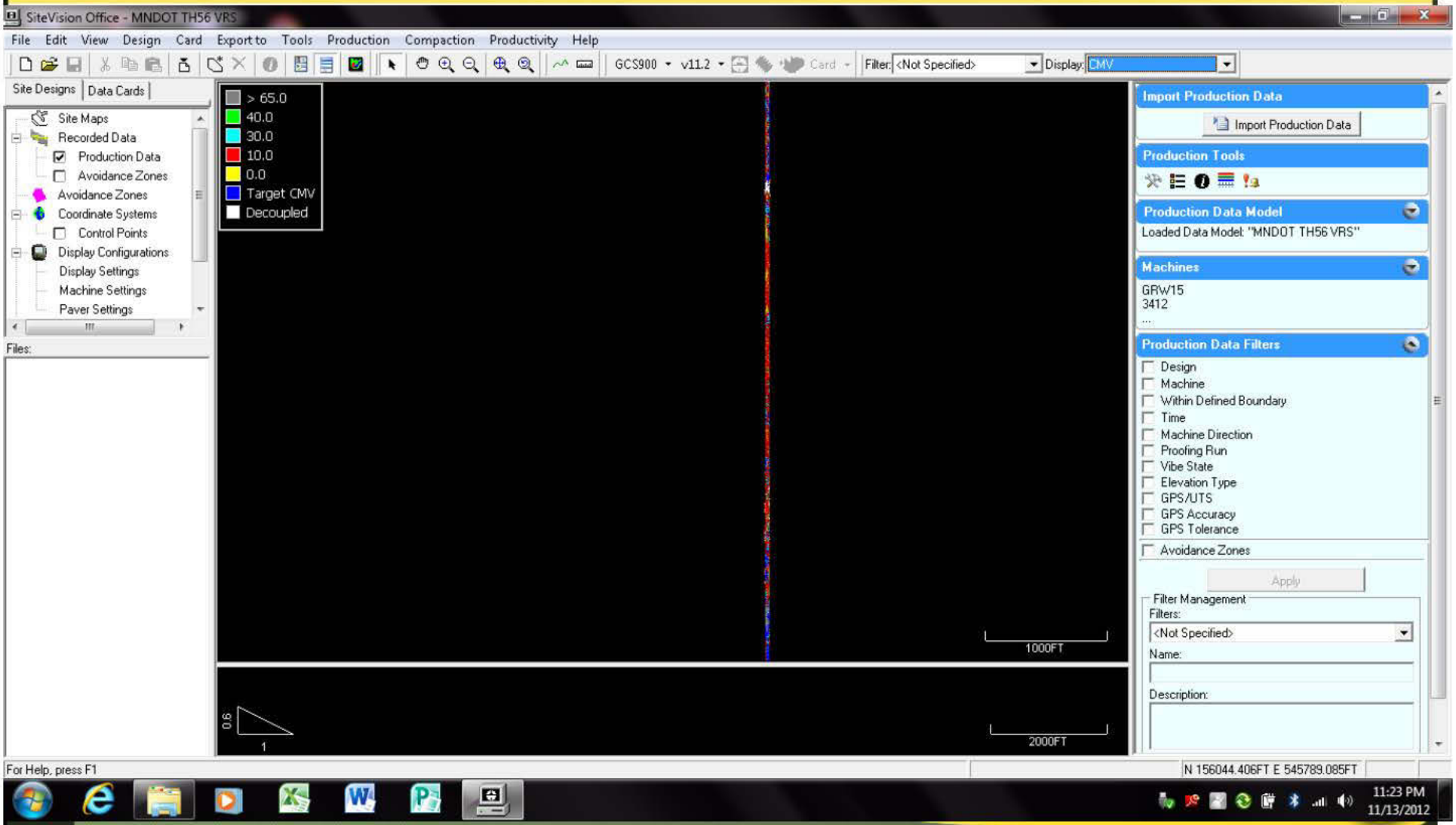
Troubleshooting

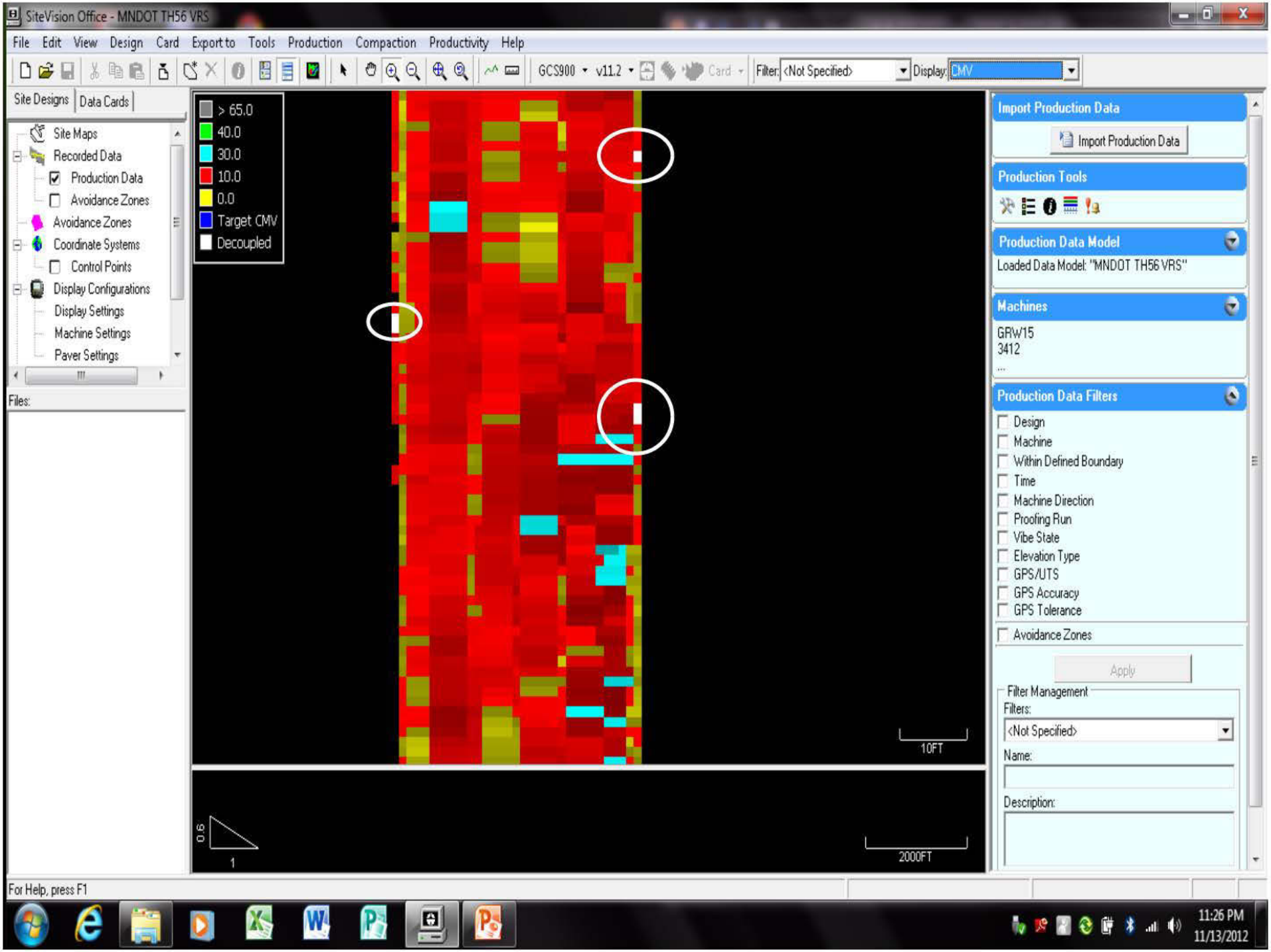
- Radio issues
  - Delayed response
- Sensor issues
  - Replacement of parts
- Breakdowns
- Communication issues
  - Monitor working
  - Data not Transmitted
  - Have backup Plan.

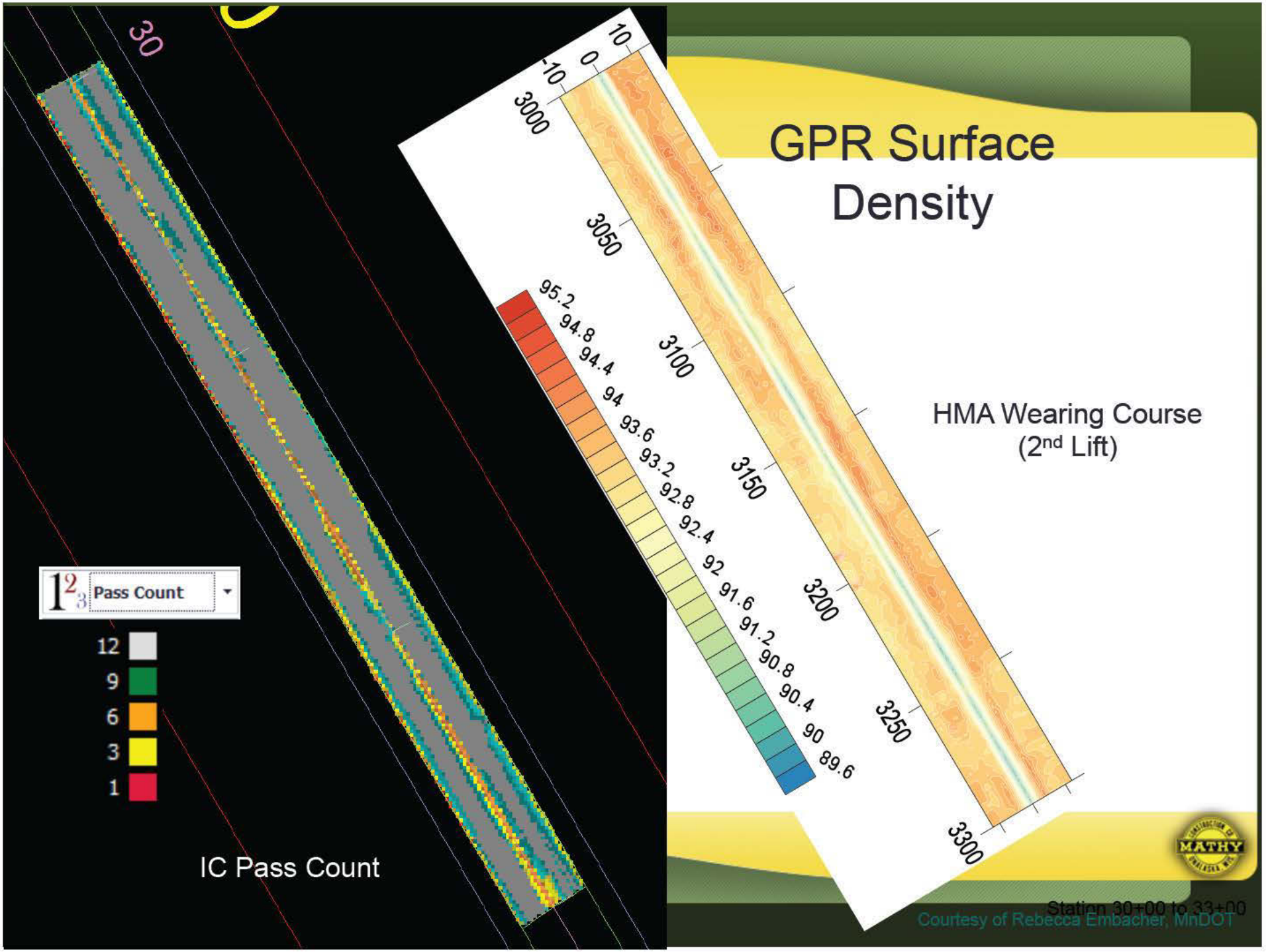
View from the office



View from the office




SiteVision Office - MNDOT TH56 VRS
File Edit View Design Card Export to Tools Production Compaction Productivity Help
GCS900 v11.2
Filter: <Not Specified>
Display: CMV
Site Designs
Data Cards
Site Maps
Recorded Data
Production Data
Avoidance Zones
Avoidance Zones
Coordinate Systems
Control Points
Display Configurations
Display Settings
Machine Settings
Paver Settings
Files:
> 65.0
40.0
30.0
10.0
0.0
Target CMV
Decoupled
10FT
0.6
1
2000FT
Import Production Data
Import Production Data
Production Tools
Production Data Model
Loaded Data Model: "MNDOT TH56 VRS"
Machines
GRW15
3412
...
Production Data Filters
Design
Machine
Within Defined Boundary
Time
Machine Direction
Proofing Run
Vibe State
Elevation Type
GPS/UTS
GPS Accuracy
GPS Tolerance
Avoidance Zones
Apply
Filter Management
Filters:
<Not Specified>
Name:
Description:
For Help, press F1
11:26 PM
11/13/2012

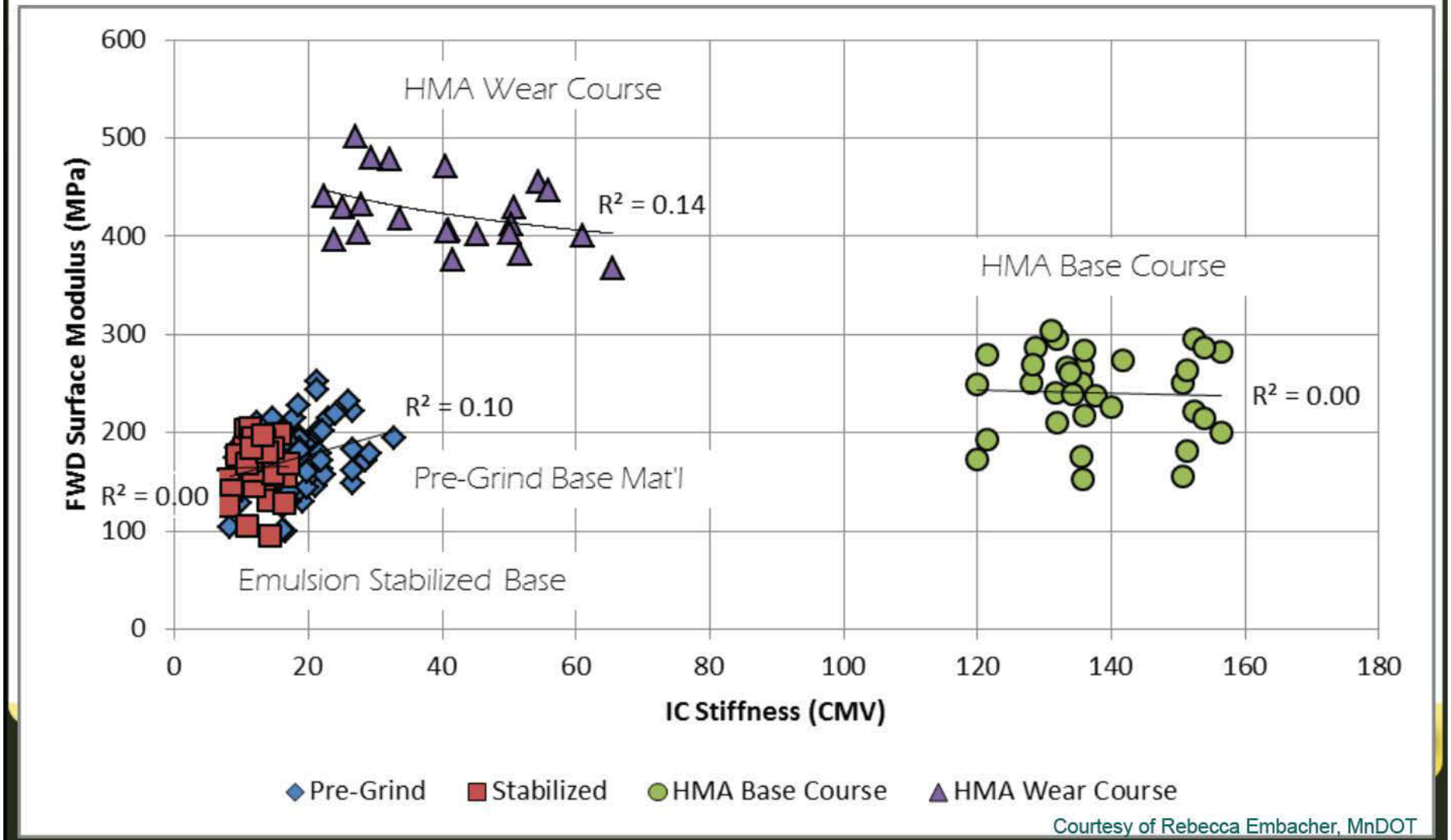

GPR Surface Density
HMA Wearing Course
(2nd Lift)
10
0
-10
3000
3050
3100
3150
3200
3250
3300
95.2
94.8
94.4
94
93.6
93.2
92.8
92.4
92
91.6
91.2
90.8
90.4
90
89.6
Pass Count
12
9
6
3
1
IC Pass Count
Station 30+00 to 33+00
Courtesy of Rebecca Embacher, MnDOT

Data Transfer – Th 56

- Directly from roller to web-base storage (cloud technology).
- At least one time per day.

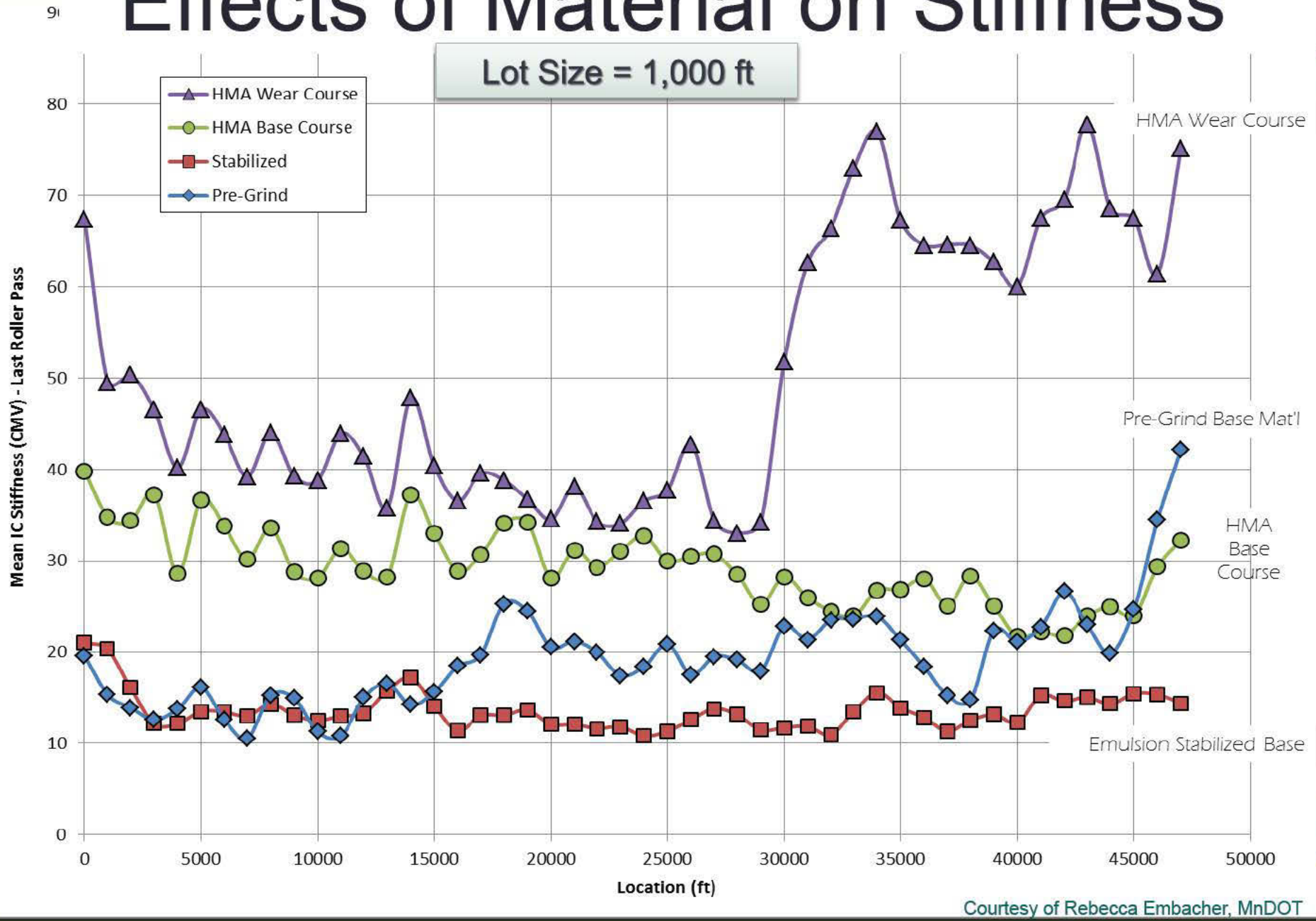
Courtesy of Rebecca Embacher, MnDOT

Correlation between FWD & IC



Courtesy of Rebecca Embacher, MnDOT

Effects of Material on Stiffness



Courtesy of Rebecca Embacher, MnDOT

Target Values

Unable to implement a target stiffness or pass count as part of QA.

COMPLEX

(It has never been successfully achieved in MN)

QC only at this time.

Courtesy of Rebecca Embacher, MnDOT

Smoothness Results

- IRI Ride results – inches/mile
  - Th56 Dodge 30.9
  - Th56 Goodhue 31.8
  - Th57 Goodhue 37.0
  - CAH 13 30.0

Density Results

- Density Averages - $\%G_{mm}$
  - Th56 94.6
  - Th57 94.3
  - CSAH 13 95.3

Summary

Quality Management

- Complete rolling documentation
- Stiffness
  - Varies with machine/manufacturer
  - Not correlated to current density specifications
  - No direct correlation to pavement performance models.
  - Huge data files

Summary

Intelligent Compaction can be used for:

- Pre-paving site surveys.
- Project mapping and
- Quality Control
- Real time measure of consistency.

Conclusion

- Standard rolling and paving practices need to be followed
  - Ø IC doesn't drive the equipment for you!

- IC is a developing technology for performance based acceptance.

Future Work

- Develop standards for stiffness measurements
- Correlate stiffness to pavement performance
- Integrate with 3D project control

Acknowledgements

- FHWA – Lee Gallivan
- Transtec – George Chang
- WisDOT – Bob Arndofer, RobinStafford
- MnDOT – Rebecca Embacher
- Mathy Construction and
  - American Asphalt Division
  - Rochester Sand and Gravel Division